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CELA RESEARCH REPORT

MODES OF MEANING IN HIGH SCHOOL SCIENCE

RICHARD F. YOUNG
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CELA RESEARCH REPORT NUMBER 15001

NATIONAL RESEARCH CENTER ON

ENGLISH LEARNING & ACHIEVEMENT

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Modes of Meaning in High School Science

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Modes of Meaning in High School Science

Richard F. Young
Hanh Thi Nguyen

Introduction: Teachers, Textbooks, and Science

In schools around the world students are exposed to instructional input from a variety of sources. In many situations, teachers provide a large part of that input by spoken interaction with their students, but instructional input is also available from other sources that include fellow students, textbooks, teacher-produced materials, and instructional media ranging from the chalkboard to the computer. Each of these various inputs to students has characteristic situational and linguistic properties such that we may regard each as a distinct mode in which meaning is made in the language of instruction. One example of this is the difference between the characteristics of the spoken English used in classroom interaction between teacher and students and the written English of the students' textbooks. In this paper, we will be concerned to describe differences between these two modes of meaning and to draw implications from them for the complementary and overlapping ways in which the two modes construct the subject matter of instruction.

Thanks to a research tradition going back at least 30 years, we now know much about the differences between speech and writing as modes of communication and the differences between spoken and written English in particular (Biber, 1988; Chafe & Tannen, 1987; Halliday, 1989; Kroch & Hindle, 1982; McCarthy, 1998; Tannen, 1982; and see Atkinson & Biber, 1994, for a review). The functional and formal distinctions that have been identified between speech and writing are, of course, applicable to a very wide range of specific instances of spoken and written texts. Thus while this high level distinction will be useful in understanding major differences between teacher talk and textbooks, there are also more specific differences due to the educational context of these instances of speech and writing. Again, we have considerable knowledge about the characteristics of spoken language used in classrooms (Barnes, Britton, & Rosen, 1971; Lemke, 1990; Mehan, 1979; Sinclair & Coulthard, 1975) and about the written registers of school textbooks (Biber, 1991; Halliday & Martin, 1993; Martin, 1985; Taylor, 1983).

However, we are not aware of any research that has compared the presentation of related instructional material by the teacher and in the textbook. To understand the degrees to which textbook and teacher presentations of related subject matter overlap and complement each other is an interesting applied linguistic undertaking, as is any investigation of variation. However, such a study is also relevant to several other fields besides applied linguistics. First, in the social construction of disciplinary knowledge, it is important to understand how novices are socialized into both the written and spoken practices of the field. Second, in educational practice, curricula may be better designed and teachers' instructional practices may be better informed if teachers and textbook authors understand the differences between how knowledge of a field is constructed through live face-to-face interaction and through a textbook. These two questions motivate the study that we report on here.

Our central concern in this paper is to understand how the teacher and the author of the textbook construct and communicate scientific meaning. And the point of departure for our analysis is the language that the teacher and textbook writer use to do so. By starting our analysis with language, however, we are not limited to a study of the formal features of lexical and syntactic structure. Rather, we consider language as a system of resources for making meaning, and we argue that the ways in which meanings are constructed in high school science differ from the ways that other communities create meaning. Thus the task of the high school student of science does not only consist of learning scientific facts and relationships, but the student is also an apprentice in the ways in which this community creates meaning. Teaching and learning high school science is a means by which a community of individuals sustains the shared beliefs and values of the community through the ways in which they construct meaning.

The specific question of how certain students, their teacher, and the author of their textbook construct meaning is a piece of the more general question of the relationship between language and human experience. The general question is: In what ways does the language of a particular human activity influence the ways that people participate in the activity and understand it? Our assumption is that the way that language is structured in a particular activity is a theory of how the participants experience that activity. This contrasts with other ways of understanding experience; for example, it differs from an attempt to understand experience by asking people to describe it or by recording how they reflect on their experience or by speculating how other activities are related to the focal experience. As practiced by ethnographers, this approach

attempts to understand experience by putting an activity in a broader context of other activities and other experiences. Studying language as a theory of experience is a semiotic theory in which the question "How is meaning made?" is central; it also differs from approaches such as conversation analysis that examine in detail the sequential patterns of talk in interaction but do not go beyond this analysis to relate those patterns to the experience of the participants. A focus on talk alone is insufficient for understanding how reading a textbook differs from participating in a class discussion and, more important, although understanding the structure of talk is essential to understanding the process of meaning making, semiotics is absent from conversation analysis.

In this paper we are concerned with one specific school subject: 12th grade physics. The ways that students experience physics is through language that is at times esoteric and involves some new uses of language. In contrast with commonsense knowledge of students' lives that is habitual and constructed in familiar language, knowledge of physics is – like much other school knowledge – uncommonsense (Christie, 1998). In order to understand how that knowledge is created in talk and in text we will adopt the methods of systemic functional grammar. This is the principal method by which linguists and educationists have studied the resources of meaning making in language. The study of systemic functional grammar was initiated by Michael Halliday and made widely accessible by his own work (1994) as well as that of Eggins (1994), Martin (1992), and Thompson (1996). Its methods have been applied to the study of education by many scholars including Christie (1989), Christie and Martin (1997), and Lemke (1990). The present paper follows the systemic functional tradition by presenting first the two focal instances of language by teacher and textbook. We carry out a detailed systemic analysis of the ways in which these two texts construct scientific meaning, focusing on the similarities and differences between them. And we conclude by discussing the implications of our findings for the socialization of students to science discourse through different instructional modes.

Two Texts

The focus of the present study is a 12th-grade physics class that was videotaped regularly during the spring 1997 semester at an inner-city high school in the American Midwest. A total of 24 class periods were taped and field notes made of the print materials were used by the students in and out of class. The data were collected as part of a longitudinal project on academic language socialization (Ford, Zuengler, & Young, 1995). We report in this paper on a study of the

presentation of one topic from a class period about half way through the semester and the presentation of the same topic in the textbook. The topic of the lesson and the textbook is reflection in a plane mirror. The two texts on which we focus are presented below. Figure 1 is a transcript of approximately one minute's classroom interaction from a going-over-the-homework session of a class It begins with a student's question to the teacher and ends when the teacher overtly closes the topic by saying "But I don't wanna spend any more time on this" and then moving on to a different activity.[1]

Activity Type	Turn #	Speaker	Transcript
STUDENT-QUESTIONING	197	C:	If he moves then how far he is away.
DIALOGUE	198		(.)
	199	T:	Well as he moves away,
	200	C:	If he's three feet away, would he be smaller?
	201		(.)
TEACHER EXPOSITION	202	T:	Nuh- Well, think about it. (.) If I- If I'm standing here, and looking at my face, Okay here- here Let's say this is maybe easier to [see.
	203	?:	[Like (um gree)
	204	T:	I'm looking at my eyeballs and I'm gonna see the top of my head, (.) so I have to look up at an angle about that much. (.) Right? Cuz ^I'm this height.
	205		(.)
	206	T:	As I move away, (.) does my height get different? = No.
	207	?:	°No.°
	208	T:	I look smaller, because I'm farther away, right?
	209	?:	Yeah.
	210	T:	But really my- the height- my eye- now look at the rays from my eyes, ehhhhhhh- ((machine gun pitch)) They're still going at the same- (.) angle, aren't they.
	211	?:	Yeah. =
	212	T:	Uhhhehh:::: ((machine gun pitch)) So I must be the same height.
	213	?:	[You s-
	214	T:	[I look smaller cuz I'm farther away.
	215		(.)
STUDENT-QUESTIONING	216	D:	So then it would be one quarter, would [n't it?
DIALOGUE	217	T:	[I don't know.
CLASSROOM BUSINESS	218	T:	[But I don't wanna spend m- any more time on this, =
	219	?:	[(°It could be the°)
	220	T:	= We'll talk about this after the lab.

Figure 1. Transcript of Part of a 12th-Grade Physics Lesson on the Topic of Reflection in a Plane Mirror.

The textbook assigned to the class is *Conceptual physics* (Hewitt, 1992) and we show in Figure 2 a passage two paragraphs (20 lines) long that begins immediately under the section heading "29.3 Mirrors" and ends just before the topic shifts in the third paragraph to reflection in a curved mirror.

Mirrors

Consider a candle flame placed in front of a plane (flat) mirror. Rays of light are reflected from its surface in all directions. The number of rays is infinite, and every one obeys the law of reflection. Figure 29–4 shows only two rays that originate at the tip of the candle flame and reflect from the mirror to someone's eye. Note that the rays diverge (spread apart) from the tip of the flame, and continue diverging from the mirror upon reflection. These divergent rays *appear* to originate from a point located behind the mirror. The image of the candle the person sees in the mirror is called a **virtual image**, because light does not actually pass through the image position but behaves virtually as if it did.

Your eye cannot ordinarily tell the difference between an object and its reflected image. This is because the light that enters your eye is entering in exactly the same manner, physically, as it would if there really were an object there. Notice that the image is as far behind the mirror as the object is in front of the mirror. Notice also that the image and object have the same size.

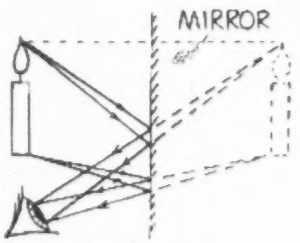

Fig. 29–4 A virtual image is formed behind the plane mirror and is located at the position where the extended reflected rays (broken lines) converge.

When you view yourself in a mirror, your image is the same size your identical twin would appear if located as far behind the mirror as you are in front—as long as the mirror is flat.

Fig. 29–5 For reflection in a plane mirror, object size equals image size and object distance equals image distance.

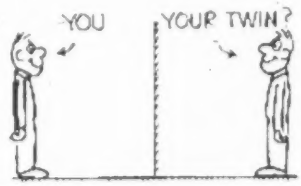

Figure 2. Extract from a High School Physics textbook on the Topic of Reflection in a Plane Mirror. *Source*: Hewitt, P. G. (1992). *Conceptual physics: The high school science program* (2nd ed.), pp. 433-434. Menlo Park, CA: Addison-Wesley.

These two texts are small because this is a study carried out in order to demonstrate two characteristics of a systemic functional analysis of classroom discourse. We will demonstrate the focus that such an analysis brings to the linguistic resources that are used in the construction of knowledge in the content area of science, and we will show the relationship between teacher talk

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and the literacy that students must learn to use in the school subject. The conclusions that we draw from this analysis are tentative because they are based on a small amount of data, but they nonetheless bear comparison with systemic functional analyses of other corpora of interactions and texts in the science classroom (Christie, 1998; Halliday & Martin, 1993; Martin & Veel, 1998; Schleppegrell & Colombi, 2002; Wells, 2000). Before beginning our analysis, we also wish to distinguish our approach from that of others working on similar problems of instructional discourse. First, we stress that in comparing these two texts, we treat them as exemplars of two modes that interest us. We are not considering them primarily as inputs to the students in this particular class, for while we can identify the students that participated in the lesson, we cannot be sure which of them – if any – read the passage in the textbook. Second, our analysis of the teacher talk makes only occasional reference to the interactional nature of the discourse, and we carry out our analysis of the textbook with barely a mention of the interaction in real time between reader and text. In other words, we have severely limited our focus on interaction in this paper. We do this not because we believe that interaction is not important to the understanding of instruction – quite the reverse is true – but rather because we wish to make a semantic and functional analysis of two texts and to compare the ways in which linguistic resources are used in them. An interactional analysis of the two texts could be done, but it is not our central focus and there is no space for it in this paper.

Because we are looking through these texts at a high school science lesson, it will be important to understand the ways in which science – in particular physics – is done through language. Here, again, there is an extensive literature on many aspects of language in scientific activity (Bazerman, 1988; Elliot, 1975; Gunnarsson, 1993, 1997; Halliday, 1988; Halliday & Martin, 1993; Harris, 1990; Jacoby, 1998; Jacoby & Gonzalez, 1991; Lemke, 1990; Myers, 1985, 1994; Ochs & Jacoby, 1997; Ochs, Jacoby, & Gonzalez, 1994; Parsons, 1990; and see also the bibliography of empirical studies of scientific register in Atkinson & Biber, 1994). The language of school science textbooks has been a topic of particular interest in the United Kingdom and in Australia, resulting in the U.K. schools-based *Reading for learning in the sciences* project and the work carried out in the systemic-functional linguistic framework in Australia (Halliday & Martin, 1993; Martin, 1985). It is this latter framework that we have adopted in our present analysis.

SYSTEMIC-FUNCTIONAL ANALYSIS OF THE TWO TEXTS

There are clear advantages to a systemic-functional analysis of these texts since we are concerned to elucidate how each works as an instance of communication. In our analysis, we have followed quite closely the methods used by Halliday and Martin in *Writing science: Literacy and discursive power* (Halliday & Martin, 1993). We have done so because the systemic-functional analysis that Halliday and Martin provide is more empirically based than other systemic functional analyses we have seen and also because their analysis was developed to deal with science texts similar to the written text that we are investigating here. Our analysis focuses on three ways in which meaning is communicated through the two texts: (1) the means by which physical and mental reality is construed in the texts, (2) the degree of abstractness or concreteness of the texts, and (3) the rhetorical structure of scientific reasoning that the texts demonstrate. These three features relate to the ideational metafunction, lexical packaging through technicality and grammatical metaphor, and the textual metafunction.

Ideational Metafunction – Modes of Meaning

Halliday and Martin (1993) recognize three complementary ways in which texts construe the world: Texts typically represent the *material processes* of the physical and biological world; they are also attempts to influence the social and cognitive world through *verbal and mental processes;* moreover, they represent the world through the *relational processes* of self-reference. Examples of these three processes from the texts follow.

Material processes construct "a world of action in which physical and biological entities interact, by themselves, or on other things" (Halliday & Martin, 1993, p. 27) and are typically represented by verbs of action. For example,

> Rays of light *are reflected* from its surface in all directions. (Textbook, page 433)
>
> As I *move away*, does my height get different? (Teacher talk, turn 206)

Verbal and mental processes construct "a world of semiotic activity in which typically conscious entities negotiate meaning" (Halliday & Martin, 1993, p. 27) and are often realized by verbs denoting internal psychological or perceptual states. For example,

Consider a candle flame placed in front of a plane (flat) mirror. (Textbook, page 433)

Nuh- well, *think* about it. (Teacher talk, turn 202)

Relational processes construct "a world of relationships among entities – a world in which things can be without doing" (Halliday & Martin, 1993, p. 28) and are often represented by copula "be" and copula-like constructions. For example,

Your image *is* the same size your identical twin would appear. (Textbook, p. 434)

I *look* smaller, cuz I'*m* farther away. (Teacher talk, turn 208)

Table 1. Material Processes (Expressed by Action Verbs) in the Teacher Talk and Textbook

Teacher Talk	Textbook
"I'*m standing* here" (turn 202)	a candle flame *placed* in front of a plane (flat) mirror
"and *looking* at my face "(turn 202)	rays of light *are reflected* from its surface
"I'm *looking* at my eyeballs" (turn 204)	two rays that *originate* at the tip of the candle flame
"I *have to look up* at an angle" (turn 204)	[two rays that] *reflect* from the mirror
"I *move* away" (turn 206)	the rays *diverge* (spread apart) from the tip of the flame
"they're still *going* at the same angle" (turn 210)	[the rays] *continue diverging* from the mirror
	light *does not* actually *pass* through the image position
	as if it *did* [pass through the image position]
	the light that *enters* your eye
	[the light] *is entering* in exactly the same manner
	when you *view* yourself in a mirror

Tables 1–3 allow us to compare the ways in which these two texts realize these three modes of meaning, and we find similarities and differences between them. Comparing first material processes in Table 1, we find that both the textbook author and the teacher use material processes with high frequency, probably because of the expository nature of the two texts. A marked difference, however, is that while the textbook uses passive voice for the two action verbs "placed" and "are reflected," the teacher talk has no passive voice at all. The teacher's active action verbs are mostly first person, and even when the verb is third person, the referent is still the teacher, as in "does my height get different?" A consequence of this difference is that the teacher talk places the teacher at the center of the action – a participant in the material process of reflection in a plane mirror – and indexes a direct and live relationship between the speaker and

his audience. A good example of the participation of the teacher in the scientific process he describes is the way he casts himself in turns 210–212 as a cartoon character, a role that may have emotional appeal to his teenage students.

> T: But really my- the height- my eye- now look at the rays from my eyes, eh-eh-eh-eh-eh-eh-eh ((imitates the sound of a machine gun)) they're still going at the same- (.) angle, aren't they.
>
> ?: Yeah.=
>
> T: Uh-uh-uh-uh-uh-uh ((imitates the sound of a machine gun)) So I must be the same height.

In contrast, third-person verbs in the textbook cast the writer and the reader as observers, and keep the reader at a distance from the process. In so doing, the textbook presents scientific processes as observed objective entities independent of the reader and the writer, while the teacher brings science into the lived relationship between the speaker and the hearer. Thus while the textbook casts the reader as an observer, the teacher casts himself – and by implication his students – as participants.

Table 2. Mental Processes (Expressed by Verbs Denoting Psychological or Perceptual States) in the Teacher Talk and Textbook

Teacher Talk	Textbook
"Well, *think* about it" (turn 202)	*Consider* a candle flame placed in front of
"Let's *say*" (turn 202).	Figure 29-4 *shows* only two rays
"I*'m gonna see* the top of my head" (turn 204)	*Note* that the rays diverge
"now *look* at the rays from my eyes" (turn 210)	the image of the candle the person *sees* in the mirror
	your eye *cannot* ordinarily *tell*
	Notice that the image is as far behind the mirror as…
	Notice also that

Turning now to verbal and mental processes, as Table 2 shows, the textbook appears to have a slightly higher density of verbs representing mental processes than is evident in the teacher talk. The textbook author tries by means of imperative mood to direct the reader's mental processes. For example, the textbook reads, "*Consider* a candle flame placed in front of a plane (flat) mirror," "*Note* that the rays diverge," "*Notice* that the image is far behind the mirror," and "*Notice* also that." On the other hand, the teacher invokes mental processes at the beginning of his

exposition, which serves to focus his students' attention and engage their cognition: "Well, *think* about it" (turn 202), and "Let's *say*" (turn 202). And then only once more, in turn 210, he directs students' attention to his nonverbal imitation of light rays: "now *look* at the rays from my eyes."

The slight discrepancy between the textbook and the teacher talk may perhaps be explained by the different modes of communication: The text is the only medium available to the textbook writer to direct the readers to the points he wants them to focus on. The teacher, on the other hand, can focus his students' attention by his body movement, facial expression, gaze direction, finger pointing, and the prosody of his speech as well as linguistically by means of verbs denoting psychological or perceptual states.

Table 3. Relational Processes (Expressed by Copula Constructions) in the Teacher Talk and Textbook

Teacher Talk	Textbook
"this is maybe easier to see" (turn 202)	The number of rays *is* infinite
"I *'m* this height" (turn 204)	and every one *obeys* the law of reflection.
"Does my height *get* different?" (turn 206)	The image of the candle the person sees in the mirror *is called* a virtual image
"I *look* smaller" (turn 208)	but *behaves* virtually as if it did.
"I *'m* farther away" (turn 208)	This *is* because
"I *must be* the same height" (turn 212)	the image *is* as far behind the mirror
"I *look* smaller" (turn 214)	as the object *is* in front of the mirror.
"I *'m* farther away" (turn 214)	the image and object *have* the same size.
	your image *is* the same size

Finally, relational processes in both the textbook and the teacher talk are realized most often by copula "be." As Table 3 shows, however, the textbook author uses a far wider range of ways of expressing relational meaning in the textbook than does the teacher. The teacher talk contains only the copula "be" and one other verb: "look" in "look smaller." The textbook, on the other hand, not only has copula "be" and verbs of near-being, it also has a wide range of less obviously relational verbs such as "every one *obeys* the law of reflection," "the image … *is called* a virtual image," and "[light] … *behaves* virtually as if it did."[2] This greater range of vocabulary for expressing relational processes in the textbook has the advantage of precision but, at the same time, it may make it harder for the readers to comprehend that a relation between entities is being described.

Lexical Packaging through Technicality and Grammatical Metaphor

Halliday & Martin (1993, p. 29) discuss several ways in which meaning is condensed in scientific discourse. One way is by the use of technical terms, which "compact information on the content 'plane'. . . . Once defined the technical term can be assumed in place of the more cumbersome commonsense wording." Another way of condensing meaning frequently used in science discourse is by means of grammatical metaphors such as nominalization. Nominalizations encode multiple meanings in each noun phrase and, in order to derive the commonsense meaning of a nominalized phrase (a process that we refer to as unpacking), the reader needs to use the co-text and the more general context of the text. For example, a compact noun phrase such as "the law of reflection" is a grammatical metaphor for the non-nominalized phrase "the law of how things reflect light." The technical term "reflect" also needs to be unpacked in order to yield the commonsense meaning, "the law of how light bounces back when it hits things."

Since these kinds of condensed meaning are characteristic of science texts, it is not surprising that both technical terms and nominalizations are frequent in both the textbook and teacher talk. The difference between the two texts lies in the degree to which the condensed meanings are explicitly unpacked within the text itself. The textbook leaves the reader to do most of the work of unpacking, while the teacher himself does all the work of explicitly unpacking in his subsequent exposition mainly by his gestures and body movement but also by answering his own rhetorical question. This difference is illustrated in Table 4.

The explicit visual unpacking that the teacher provides seems to indicate a marked difference between the teacher talk and the textbook. Moreover the nominalizations in the textbook require the reader to perform two stages of unpacking. First, the nominalization needs to be unpacked into a verb indicating a process, and then the technical term needs to be unpacked into non-technical language. Thus the condensed meanings in the textbook are removed from the base meaning by at least two levels, while those in the teacher talk are removed by only one level. In addition, the teacher is able to make extensive use of nonverbal resources to unpack technical terms, while the only nonverbal resource that is available in the textbook is a diagram. These differences highlight the need for more complex cognitive processing by the reader of the textbook than is required of the students in the class.

Table 4. Implicit and Explicit Unpacking and Packing of Condensed Meanings in the Teacher Talk and Textbook

Teacher Talk	Textbook
"I have to look up at an *angle*" → "about that much" [T indicates angle by gesture, explicitly unpacking the technical term "angle"]	a *plane* (flat) mirror → flat [Explicit unpacking of technical term]
	The law of *reflection* → the law of how things reflect light [Implicit unpacking of nominalization]
"does my *height* get different? = No." → do I look bigger or smaller? [Implicit unpacking of nominalization]	→ the law of how light bounces back when it hits things [Implicit unpacking of technical term]
→ "I look smaller…" [Explicit unpacking of nominalization in turn 206]	
	Upon *reflection* → when it is reflected [Implicit unpacking of nominalization]
"now look at the *rays* from my eyes" → ehhhhhh- ((machine gun pitch)) [T uses gesture and sound to indicate rays leaving his eyes, explicitly unpacking the technical term "ray"]	→ when light hits it and bounces back [Implicit unpacking of technical term]
	the rays *diverge* (spread apart) → spread apart [Explicit unpacking of technical term]
	These *divergent* rays → these rays that diverge [Implicit unpacking of nominalization]
	→ these rays that spread apart [Implicit unpacking of technical term]
	The image of the candle the person sees in the mirror is called… → a **virtual** image [Explicit packing of commonsense language into a technical term]

Notes: Condensed meanings are in *italics*.
Unpacking is indicated by an arrow (→).

The technical nature of scientific language is underlined in the textbook by the introduction of a new technical term "virtual image." This term is marked as new and technical by its appearance in bold face and through its explicit unpacking by the non-technical terms in the definition that precedes it: "The image of the candle the person sees in the mirror is called a **virtual image**...." This process of packing and unpacking technical language seems to be a characteristic of science instruction.

Textual Metafunction – The Rhetorical Structure of Reasoning

A third way of characterizing science texts according to Halliday and Martin (1993) is by setting out the rhetorical structure of reasoning in scientific explanations. This can be done at two levels: first, at a macro level, which shows the topical organization of the text as a whole, and then at a micro level, which sets out the conjunctive relations between adjacent clauses in the text.

Macro-Level Structure: Thematic Levels. Halliday & Martin (1993, p. 244) view texts as having different levels of thematic organization. Above the level of clausal theme, there is a *hyper-theme*, which is a clause that can predict "a pattern of clause themes constituting a text's method of development." Hyper-theme is thus a kind of overarching theme, which serves the metacognitive function of aiding the comprehension of the text as a whole. In this sense, it is similar to the topic sentence of a paragraph. Texts may also have a *hyper-new*, which is an accumulated expression of the pattern of new selections that make up the point of the text. Hyper-new is thus like a summary of the text's point and also helps comprehension of the text (Halliday & Martin, 1993, p. 247). On a yet broader level, there are *macro-themes* and *macro-news*, which relate hyper-themes together and hyper-news together, respectively. A macro-theme is "a clause or combination of clauses predicting one or more hyper-themes," while a macro-new is "a clause or combination of clauses collecting together one or more hyper-news" (p. 249). Table 5 compares the thematic organization of the textbook and the teacher talk.[3]

Table 5. Thematic Organization of the Teacher Talk and the Textbook

Teacher Talk	Textbook
Macro-Theme: CONTENT OF THE HOMEWORK (Implicit)	*Macro-Theme*: MIRRORS (i.e., Section Title)
	Hyper-Theme: Consider a candle flame placed in front of a plane (flat) mirror
	Themes: Rays of light / The number of rays / Every one (ray) / Figure 29-4 / Note / These divergent rays / The image of the candle / Light
Hyper-Theme: If he's three feet away, would he be smaller?	*Hyper-Theme*: Your eyes cannot ordinarily tell the difference between an object and its reflected image.
Themes: think / I / this / I / I / I / I / I / my height / I / I / look/they / I / I / I	*Themes*: This / The light / It / There / Notice / the object/ Notice / You / Your image / Your identical twin / You / The mirror
Hyper-New: I look smaller because I'm farther away. (turn 214)	*Hyper-New*: A plan mirror forms a virtual image of an object; the image appears to be as far in back of the mirror as the object is in front of it, and is the same size as the object. (In Chapter Review, page 449)

In the textbook excerpt, the author has an advantage that the section title serves as the macro-theme and signals the topic of the section. He also has two hyper-themes in the first sentence of each paragraph to signal their topics. The teacher talk in contrast does not seem to have an explicit macro-theme, except for the expectation that the teacher and students share of what will be done in this going-over-the-homework section of the lesson. Thus an implicit macro-theme may be inferred from the sequential organization of the lesson. The teacher talk hyper-theme, on the other hand, is provided interactionally by the student's question in turn 200 and the teacher's orientation to answer that question over the next several turns. The teacher constructs the student's question as the hyper-theme of his subsequent talk and thus teacher and students interactionally construct the hyper-theme of the teacher talk.

The thematic organization toward the end of each of the two texts differs markedly. The author provides no explicit hyper-new in the textbook immediately following the presentation of new information. No hyper-new is provided until the summary at the end of the chapter – 15 pages further on. This hyper-new is far removed from the text, and although a reader may turn to

this summary, the chapter review and material that it summarizes are not adjacent. In contrast, the teacher in turn 214 repeats his answer to the student's question in turn 200 and thus immediately and succinctly summarizes his exposition.

To summarize the thematic organization of these two texts, the textbook has an explicit macro-theme and hyper-theme, and an explicit but distant hyper-new at the end of the chapter. The teacher talk has an implicit macro-theme that may be deduced from the sequential organization of the lesson, an interactionally produced hyper-theme and an explicit and immediate hyper-new at the end of the text.

Micro-Level Structure: Conjunctive Relations between Clauses

In addition to the macro-level thematic organization of a text, clauses in a text are linked together by meaning relations that may be explicitly marked by conjunctions or, alternatively, may be implicit, that is, unmarked. Martin (1983, p.1) refers to these meaning relations as conjunction, which he defines as "the semantic system by which speakers relate clauses in terms of temporal sequence, consequence, comparison, and addition." Conjunction is thus one way in which speakers create and structure text by connecting the sense or meaning of clauses, using interclausal relations sometimes referred to as "logical".[4] Although these conjunctive relations may or may not be made explicit in a text, most clauses are connected to others through one or more of these relations. Explicit conjunctions require only that the addressee notice and understand the conjunction in the text in order to comprehend the connection between the ideas expressed in clauses; implicit conjunctive relations, however, require the addressee to bring extra-textual knowledge to bear in order to interpret the connection.

The teacher talk is divided into clausal units below and its conjunctive structure is outlined in Figure 3.[5, 6]

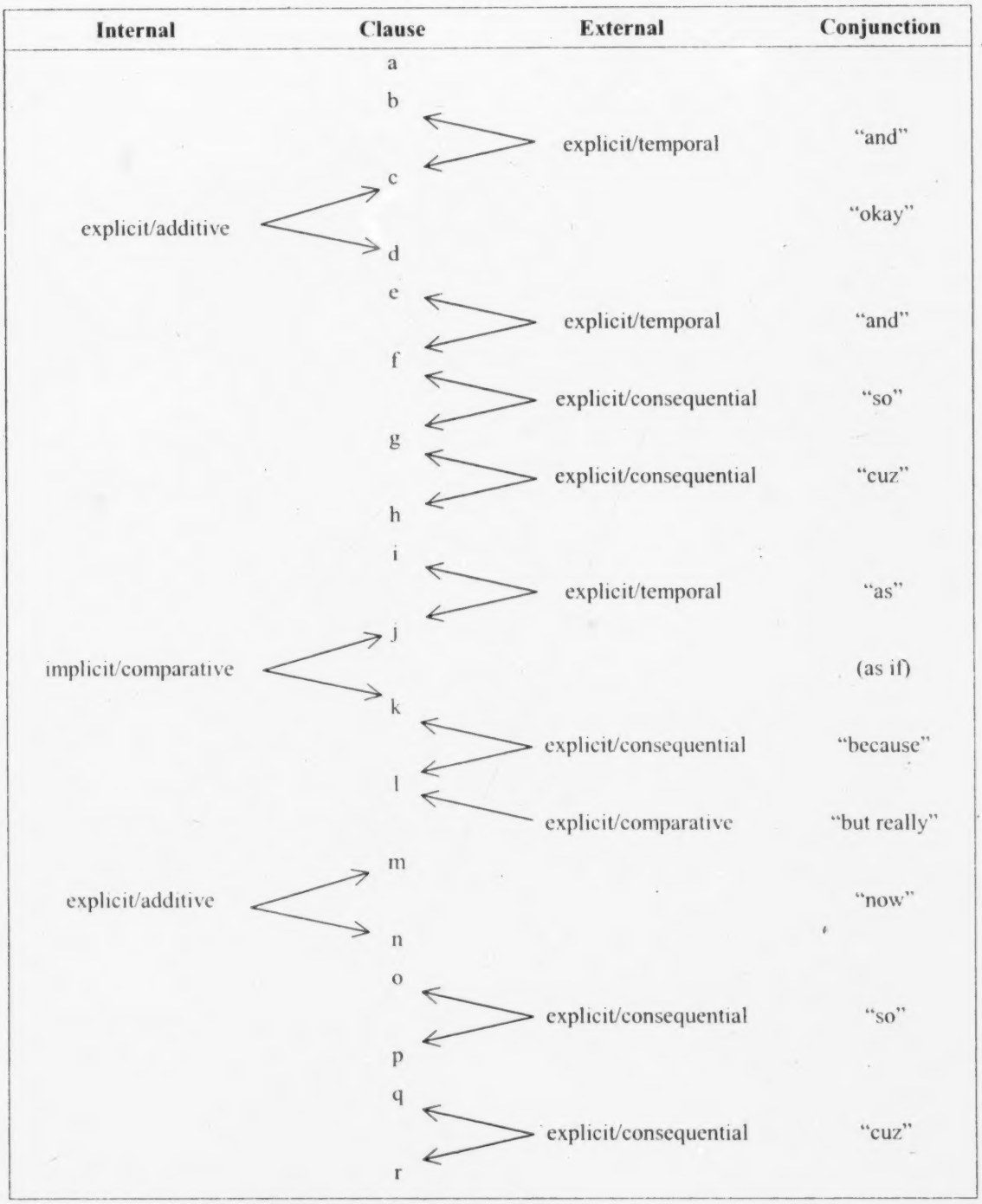

Figure 3. Conjunctive Relations in the Teacher Talk

Note: Conjunctions that may be used to make implicit relations explicit are enclosed in parentheses.

(a) Nuh- well, think about it. (b) If I'm standing here, (c) and looking at my face, (d) Okay here- here Let's say this is maybe easier to see (e) I'm looking at my eyeballs (f) and I'm gonna see the top of my head, (g) so I have to look up at an angle about that much. Right? (h) Cuz I'm this height (i) as I move away, (j) does my height get different? No. (k) I look smaller, (l) because I'm farther away, right? (m) But really my- the height- my eye- (n) now look at the rays from my eye, (o) they're still going at the same angle, aren't they. (p) So I must be the same height. (q) I look smaller (r) cuz I'm farther away.

The passage from the textbook has been analyzed into clauses in a similar way below and its conjunctive structure is presented in Figure 4.

(a) Consider a candle flame placed in front of a plane (flat) mirror. (b) Rays of light are reflected from its surface in all directions. (c) The number of rays is infinite, (d) and everyone obeys the law of reflection. (e) Figure 29-4 shows only two rays that originate at the tip of the candle flame (f) and reflect from the mirror to someone's eye. (g) Note that the rays diverge (spread apart) from the tip of the flame (h) and continue diverging from the mirror upon reflection. (i) These divergent rays appear to originate from a point located behind the mirror. (j) The image of the candle the person sees in the mirror is called a virtual image, (k) because light does not actually pass through the image position (l) but behaves virtually as if it did. (m) Your eye cannot ordinarily tell the difference between an object and its reflected image. (n) This is because the light that enters your eye is entering in exactly the same manner, physically, as it would (o) if there really were an object there. (p) Notice that the image is as far behind the mirror as the object is in front of the mirror. (q) Notice also that the image and object have the same size. (r) When you view yourself in a mirror, (s) your image is the same size your identical twin would appear (t) if located as far behind the mirror as you are in front (u) – as long as the mirror is flat.

The reticula in Figures 3 and 4 reveal a number of similarities between the two texts. The texts are very similar in length as measured by the number of clauses in each. Both the teacher and textbook author use mostly explicit conjunctions, and most conjunctive relations in both texts are "external" – that is they relate events in the physical world of light rays, mirrors, and observers that together constitute the field of discourse. Most of the conjunctive relations expressed in both texts are consequential (cause and effect) and temporal (before, after, and simultaneously), reflecting the fact that both texts are explanations through descriptions of a process. These relations – as well as comparative (contrast and similarity) and additive conjunctions – connect most adjacent pairs of clauses in both texts. The teacher appears to use more "internal" conjunctions (discourse markers like "okay" and "now") than the textbook writer in organizing the phases of his presentation for the students, which serve to make the rhetorical structure of the discourse explicit.[7] On the other hand, the layout of text in the textbook with its typographically salient heading and its visual division into paragraphs serves the same function.

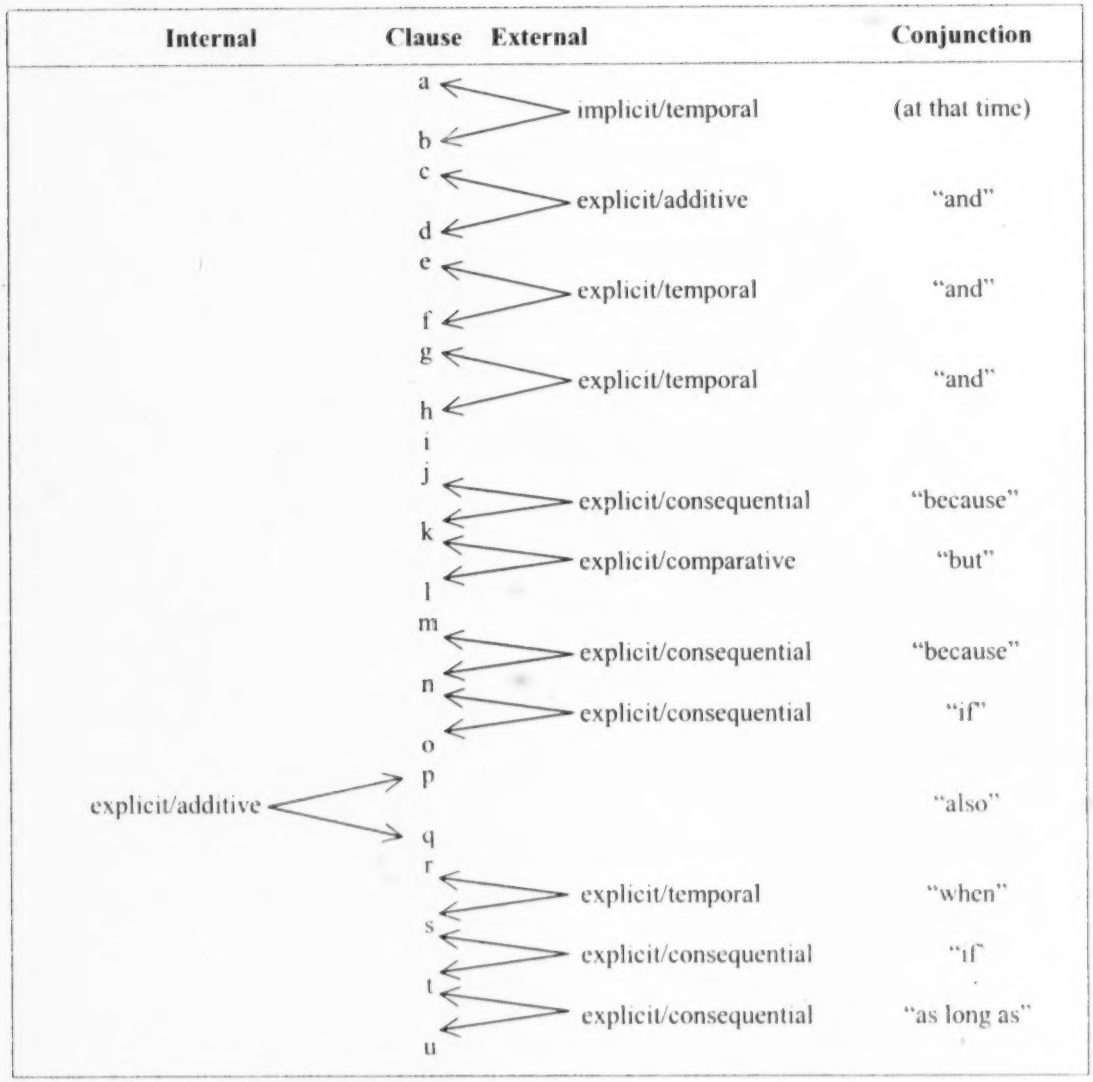

Figure 4. Conjunctive Relations in the Textbook
(Conjunctions which may be used to make implicit relations explicit are enclosed in parentheses.)

Although the conjunctive structures of the two texts appear quite similar, there is one difference between the two texts that a conjunctive analysis reveals. The largest category of conjunctions in the teacher talk comprises those consequential conjunctions expressing relations of cause and effect, and they are realized by only two lexical items: "cuz" or "because" and "so." By contrast, most conjunctions in the textbook are temporal. This difference implies that while the teacher describes relations of cause and effect explicitly, the textbook does so implicitly through the description of a process in time. The difference between teacher talk and textbook

may be attributed to differences in the modality of communication. The textbook writer has no alternative but to describe the process verbally, whereas the teacher is able to construct the process in real time through gesture and movement and only has to resort to linguistic communication to describe the relations of cause and effect.

SUMMARY

In our attempt to compare how the teacher talk and textbook function as communication, we have considered in turn the means through which physical and mental reality are construed in the two texts, the ways that lexical meanings are packed and unpacked in the two texts, and the rhetorical structure of scientific reasoning that they embody. Those similarities and differences that we have identified are summarized in Table 6.

DISCUSSION

The purpose of the analysis that we have carried out is threefold. Our basic aim is to conduct a contrastive analysis of two modes of meaning – to understand the ways in which communication of related subject matter by the teacher and the textbook overlap and complement each other. We are equally concerned, however, with two educational issues. We wish to understand, first, how the two modes socialize students differently to "uncommonsense" specific ways of thinking and talking about science. And second, we also wish to draw practical implications for the design of textbooks and for teachers' instructional practices.

Science through Talk and Text

In this report, we have compared two small sample texts from a single teacher and from a specific textbook, and it would be unwise to generalize the detailed findings of this study to other instances in which science teachers construct meaning in class or authors present science in textbooks. There are certainly teachers whose style of presentation is much closer to the discourse of the textbook, and there may be textbook authors who attempt a more interactive style of presentation than this one. Nonetheless, a study such as this, which has shown explicitly how participants in a teaching-learning situation use linguistic resources to construct meanings that are specific to the subject matter of science, confirms other studies of science instruction.

Table 6. Summary of Similarities and Differences between the Teacher Talk and Textbook

Teacher Talk	Textbook
IDEATIONAL METAFUNCTION	
High frequency of material processes	
First person action verbs in active voice	Third person action verbs in passive voice
Speaker and audience are cast in the role of participants	Writer and reader are cast in the role of observers
Fewer mental processes	More mental processes
Fewer relational verb types, transparent relational verbs only	More diverse relational verbs; transparent and non-transparent relational verbs
LEXICAL PACKAGING	
Less frequent use of grammatical metaphor	More frequent use of grammatical metaphor
Single-level grammatical metaphor	Double-level grammatical metaphor
Explicit unpacking of technical terms	Explicit unpacking of a technical term
Use of visual unpacking	No visual unpacking
	Explicit packing of a technical term
TEXTUAL METAFUNCTION	
MACRO-LEVEL STRUCTURE: THEMATIC LEVELS	
Has implicit macro-theme and explicit hyper-theme to signal coming topic	Has explicit macro-theme and explicit hyper-theme to signal coming topic
Hyper-new to summarize at end of text	Hyper-new to summarize is distant from text
MICRO-LEVEL STRUCTURE: CONJUNCTIVE RELATIONS BETWEEN CLAUSES	
Most conjunctions are explicit and internal: They connect events in the physical world	
Oral discourse markers show rhetorical structure	Typographical conventions show rhetorical structure
Teacher explains through explicit statements of cause and effect	Writer explains through description of a process

First, we can say that a basic *structure of scientific presentation* is common to the two texts we have examined: They both explain a physical phenomenon by means of describing a physical process. Second, both texts encode the process by means of action verbs, and meanings are condensed in technical terms and nominal groups. Third, both the teacher and textbook writer organize their explanations in a similar way, beginning with a macro-theme to provide a frame for the topic to follow and a hyper-new to summarize it. And finally, both texts instantiate scientific reasoning by means of a network of cause-and-effect conjunctions. These features of discourse characterize reasoning in science education and, as Martin (1993) has shown, distinguish instructional discourse in science from instructional discourse in humanities disciplines such as history.

The differences we find between the ways in which the teacher and the textbook present science result from the fact that the teacher has much better personal knowledge of the students than the textbook writer has of readers. The teacher and the students in this class have been together for at least one semester before the recording was made, and the participants know each other well, whereas the students have no personal knowledge about the author of the textbook and he has no personal knowledge of them. Indeed, one of the students comments that the teacher is "down to earth, [he] puts everything on our level." Another difference lies in this teacher's extensive use of gesture and body movement, which one of his students characterizes as presenting "things you can see."[8] In our analysis, we have seen just how the teacher does this by means of first person verbs and nonverbal communication that together cast him and his students in the role of human participants in the physical process of reflection in a plane mirror. The textbook, on the other hand, maintains a distance between the reader and the phenomenon by casting the reader in the role of a third person observer. One could say that the text helps construct the reader as objective observer, while the teacher helps construct the students as subjective participants.

Academic Language Socialization

Ochs (1986, p. 3) observed, "Sociocultural knowledge is generally encoded in the organization of discourse." When an expert in an academic discipline communicates with a novice, the organization that the expert imposes on the conversation is part of the knowledge of the field that the novice must acquire in order to become a fully-fledged member of the

disciplinary discourse community. In the situation we are describing in this paper, the teacher and textbook writer are the experts in the field of physics while the students and readers are novices. We may then ask: How does the discourse organization of the textbook and teacher talk socialize the students and readers to the discourse community of physicists?

We have already answered this question in part by showing the specific patterns of metafunction, lexical packaging, and textuality that are common to both modes because of their common pattern of explanation through process description, cause-and-effect conjunctive relations between clauses, and use of grammatical metaphor. There are differences, however, in the degree to which the textbook and the teacher use grammatical metaphor, which are more frequent in the textbook and which are not explicitly unpacked. We have also noted the subjective versus objective roles in which the students are cast by the teacher and by the textbook. Many previous analyses of written scientific register in English (e.g., those studies of research articles summarized in Swales 1990, chapter 7) have identified the same features as those found in this extract. Scientific objectivity is constructed in these texts by means of the use of passives, third person verbs, nominalizations to encode processes, and a high frequency of technical vocabulary. More recent work on the spoken discourse of lab meetings, however, has shown that in the course of making sense of scientific research, practicing scientists blur the distinction between the scientist and the physical world to "construct a referential identity which is both animate and inanimate, subject and object" (Ochs, Gonzalez & Jacoby, 1996, p. 328). In this respect, the teacher's enactment of the physical process of light reflection ("I look smaller cuz I'm farther away") is a very similar referential strategy to that adopted by the practicing physicists studied by Ochs et al. ("When I come down I'm in the domain state"). Thus the teacher's subjective, participatory approach, rather than being a popularization of the objectivity of the textbook, may be a reflection of the discourse of practicing scientists.

Teachers and Textbooks

What can be gleaned from this analysis for the design of more effective science curricula? A more specific question is: What kind of instruction is more appropriate to the spoken or the written modality? The students in this class appear to prefer the teacher's presentations to the textbook. One student commented that "[I] learn more from the teacher's discussion than from the textbook," and all students remarked that they found the class fun and interesting. Because

the students were not asked to comment on the textbook, it is impossible to judge the extent to which they used it or whether they considered it a success. We remarked earlier on the cognitively more demanding presentation in the textbook, which we attributed in part to diverse linguistic features such as passive verbs, more specific vocabulary for expressing relational processes, absence of an accessible summary (hyper-new) at the end of the passage, and – most significant perhaps – the lack of unpacking of nominalizations and technical terms. We have also suggested that this greater cognitive complexity is typical of scientific writing and the textbook is therefore providing a partial socialization into written scientific discourse.[9] Because the setting of textbook communication is private and because readers do not have to comprehend the text with the time constraints imposed by oral interaction, there is perhaps greater probability of the reader comprehending more difficult material than in class.

In contrast, the teacher in his presentation to this class exploits the nonverbal media to great advantage, using movement of his body to show the path of a ray of light and his voice in comic imitation of a machine gun. Since almost all the students mention the fact that this class is "fun," we may conclude that the teacher is also highly effective in bringing humor and positive affect into the classroom. These qualities of teacher talk are difficult to achieve in a textbook.

In conclusion, we have presented here a comparison of two modes of constructing instructional meaning carried out within the framework of systemic-functional linguistics. We have analyzed in depth a sample of teacher talk and textbook. Our results within this framework show the contrasting ways in which teachers and textbooks make meaning within the academic discipline of physics. And our analysis has several possible implications for education, including the socialization of students to ways of thinking and talking about science and the meaning-making activities that are most appropriate for live teacher presentation and those that work best in print.

NOTES

1 The oral interaction in the class is transcribed according to the conventions developed by Gail Jefferson and published in Atkinson and Heritage (1984). Speakers are identified by initial only, with the teacher identified as "T." If a speaker cannot be identified, the label "?" is used. The instructional phases of the lesson are marked using the activity types described by Lemke (1990).

2 Although in one of its senses "obey" is a behavioral process verb, it is used here to indicate the relationship between the rays of light and the law of reflection.

3 In our analysis we will only look at topical theme since our concern is to understand how the content of the argument is laid out. Topical theme in English (following Fries, 1983, p. 116) "is realized as the initial constituent of the clause or sentence."

4 Textuality may also be created through relations of reference, that is, relations between clausal constituents that have the property of referring to other constituents or to elements outside the text itself. We have already presented one of these systems in our earlier discussion of textual theme. There are also other systems, including referential relations between clauses in a text realized by anaphor, lexical linkage, and structural parallelism, as well as relations between a text and its nonlinguistic context realized by indexical expressions. We focus in this paper on conjunction because it is one of the systems by which speakers and writers reason through language, and particular patterns of reasoning have been shown to characterize particular academic disciplines. In studying the ways in which novices are socialized into the discourse practices of a particular field, it is therefore important to understand how reasoning is done through conjunctive relations in text.

5 The reticula presented in Figures 3 and 4 follow Martin (1983) and Halliday and Martin (1993). Conjunctive relations are considered either *internal* or *external*. Internal conjunctive relations have an interpersonal function and are those speech acts often realized in speech by discourse markers (Schiffrin, 1987). They are listed in the first column of the figures. External conjunctive relations, on the other hand, are meaning relations between elements of the text itself and are listed in the third column. All conjunctive relations are classified, at a primary level of delicacy, as *temporal*, *consequential*, *comparative*, or *additive*.

6 Conjunctive relations are shown only between main clauses. Subordinate clauses are considered to be part of the main clause and as such do not participate in conjunctive relations.

7 Sinclair and Coulthard (1975) were the first among many scholars to notice that teachers mark boundaries in discourse by means of a closed class of items, which Schiffrin (1987) later called discourse markers.

8 Although in this paper we have mentioned only in passing the nonverbal resources used by the teacher in his interaction with students, gesture and body movement are nevertheless important resources in a multimodal view of teaching and learning. This has been shown in recent work by Kress, Jewitt, and Ogburn (2001) and by Wells (2000).

9 Similar use of lexical resources in the construction of meaning in high school science textbooks and in professional science writing does not imply that the two are identical. As Myers (1985, 1992) has shown, university science textbooks treat scientific knowledge and the construction of scientific "facts" in a very different way from research articles written by research scientists.

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NAME OF REPORT: **MODES OF MEANING IN HIGH SCHOOL SCIENCE**

1. Your position:

____ elementary school teacher	___ state ed. agency staff	___ policy maker
____ middle school teacher	___ professional developer	___ researcher
____ high school teacher	___ school administrator	___ education writer
____ college teacher/professor	___ district administrator	other_____

2. Clarity

	Very well				Not at all	
a. The concepts in this report were clearly expressed.	1	2	3	4	5	N/A
b. This report was well organized.	1	2	3	4	5	N/A

3. Utility

a. Reading this report gave me new information or insight into teaching or learning.	1	2	3	4	5	N/A
b. This report addresses a current and important problem in education,	1	2	3	4	5	N/A
. . . and offers a solution to the problem.	1	2	3	4	5	N/A
. . . and/or helps the reader understand the problem from a different perspective.	1	2	3	4	5	N/A
c. I found the ideas and solutions offered in this report to be feasible given current realities of policy and practice.	1	2	3	4	5	N/A

4. Scholarship

a. The conclusions drawn in the report are						
. . . adequately supported by the research presented.	1	2	3	4	5	N/A
. . . fully grounded in theory.	1	2	3	4	5	N/A

5. Any other comments or suggestions regarding this report or additional research needs in the area of English and language arts teaching and learning are greatly appreciated.

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Please return this form to:

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